

**Vertical transport in deep convection
as inferred from coupling
CO₂ and other tracers measurements
to a back trajectory and a mesoscale models.**



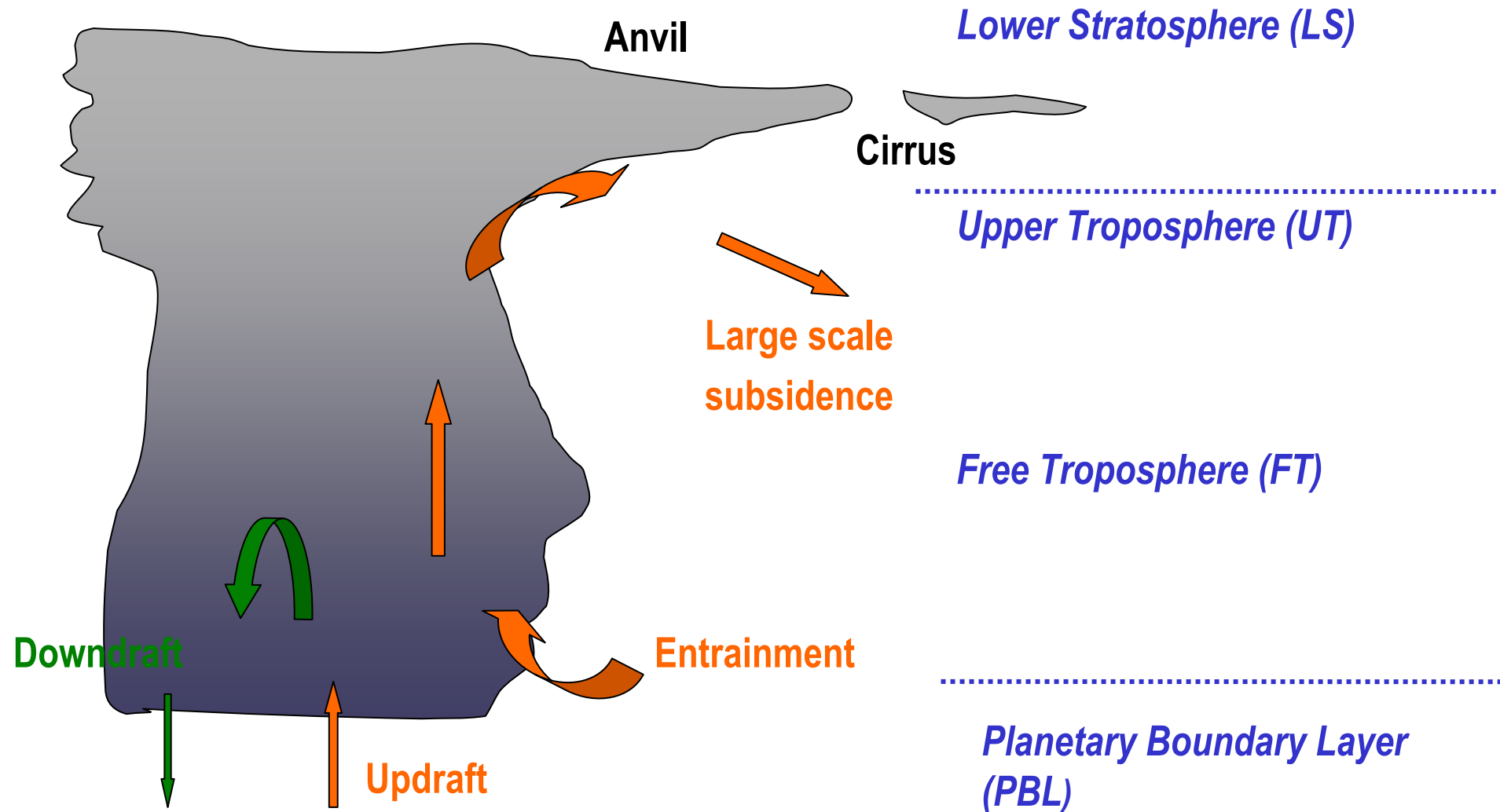
HARVARD UNIVERSITY : Irène Xueref, C. Gerbig, B. Daube, S. Wofsy,
J. Smith, E. Weinstock, J. Vellovic, D. Sayres, J. Anderson & J. Lin

NASA ARC : Ann Fridlind, A. Ackerman, E. Jensen, J. Lopez, H. Jost &
M. Loewenstein

NASA GFSC : Arlyn Andrews

NCAR : Brian Ridley, A. Weinheimer, D. Knapp & D. Montzka

NOAA : Pieter Tans, P. Bakwin & E. Richard



Interest :

Use tracers to provide integral constraints on the transport processes in convective clouds.

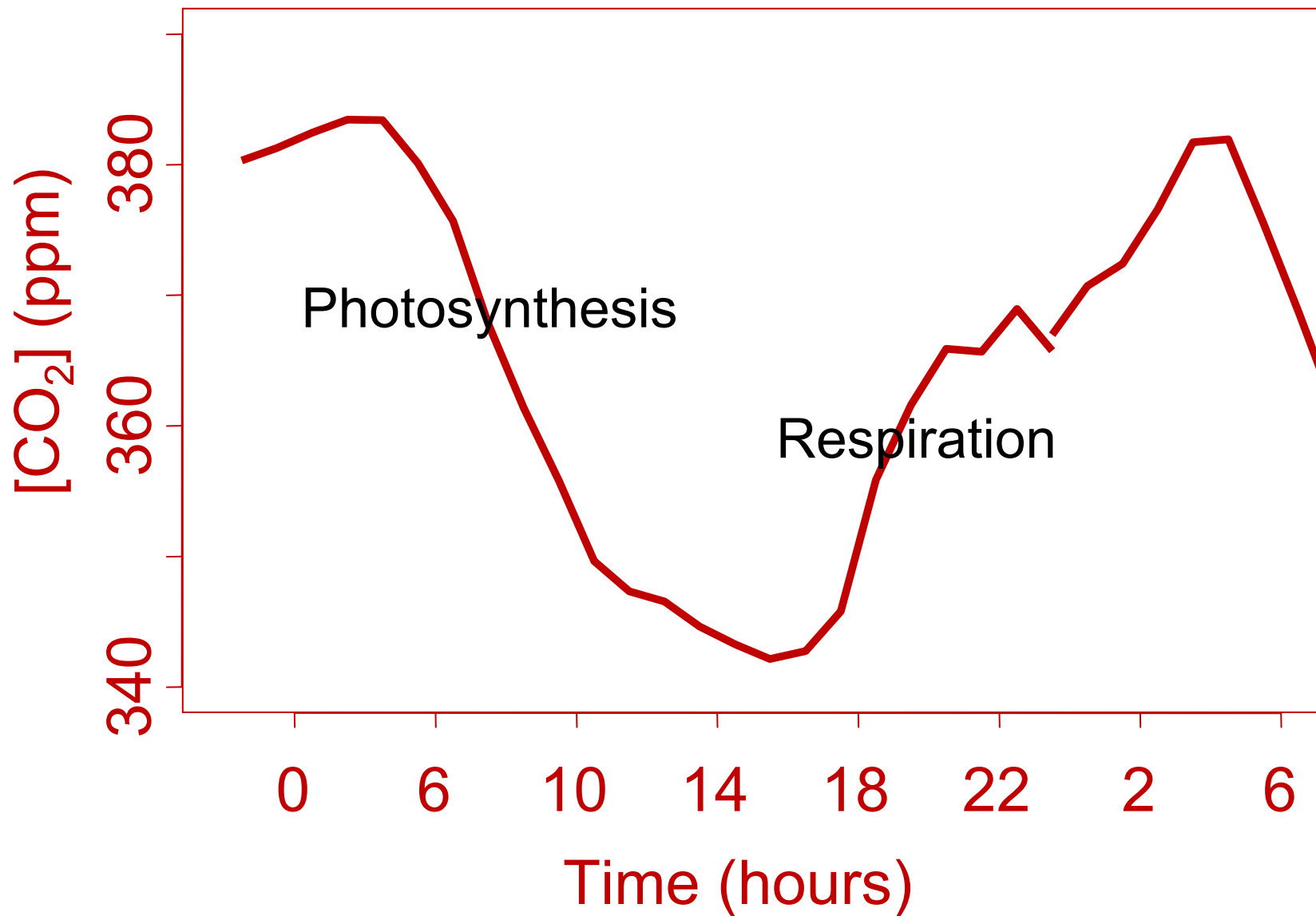
Tracers' **CONCENTRATIONS** and **RATIOS**
are function of the air mass **ORIGINS**

**CRYSTAL FACE data for CO₂, CO, O₃ and NO_x
measured on WB-57F in UT/LS are available.**

- Ocean (clean)
- Land:
 - Biosphere : CO₂
 - Biomass Burning: CO, CO₂
 - Fossil Fuel combustion : NO_y, CO, CO₂
- Stratosphere

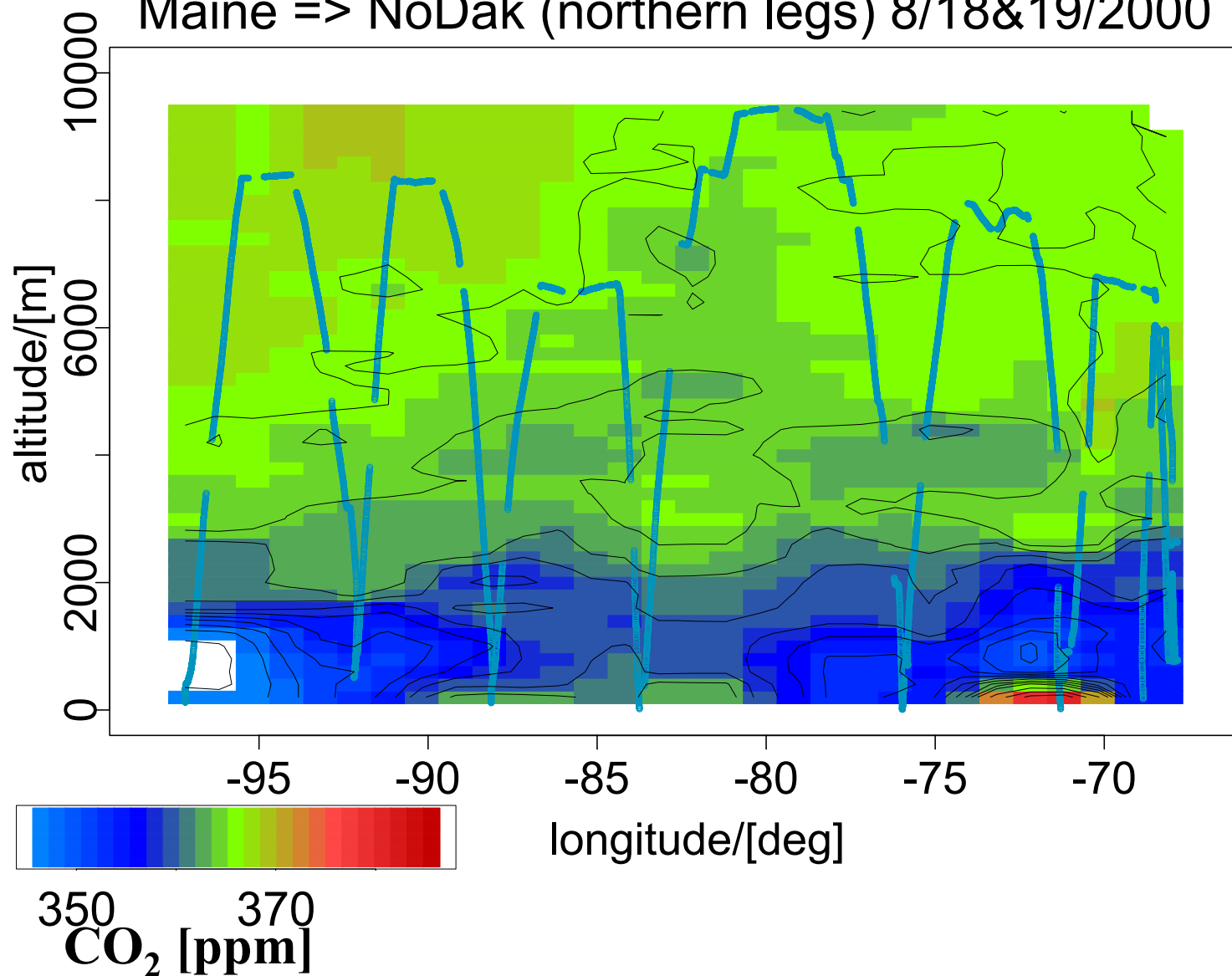
CO₂ diurnal cycle at Harvard Forest

July 16 & 17, 2002



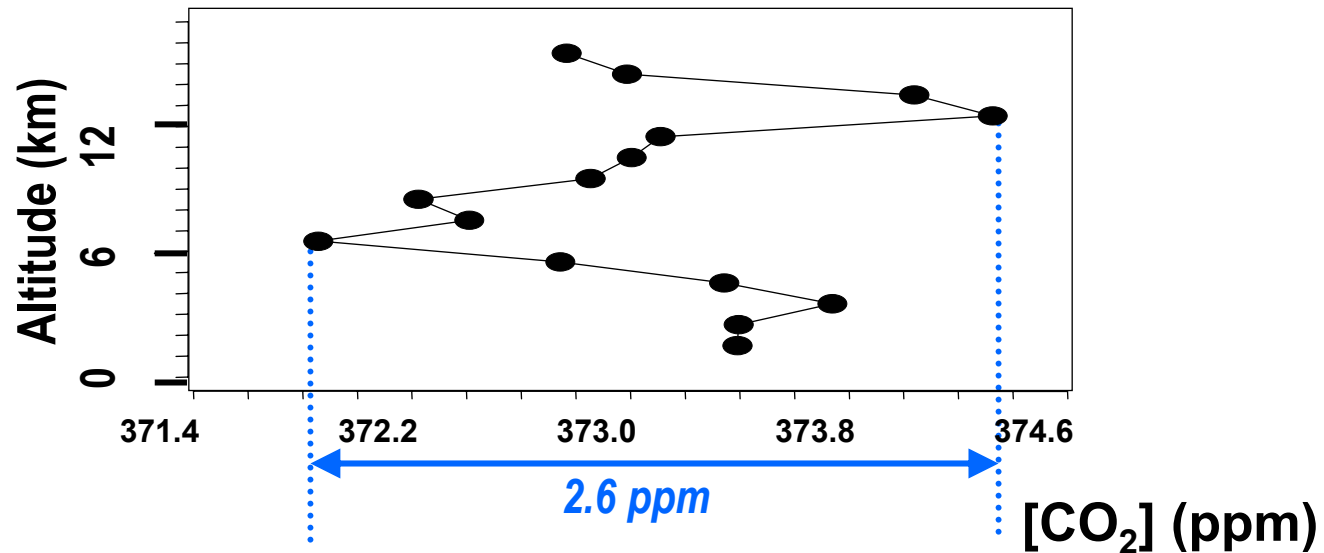
STRONG CO₂ GRADIENTS CASE

Maine => NoDak (northern legs) 8/18&19/2000

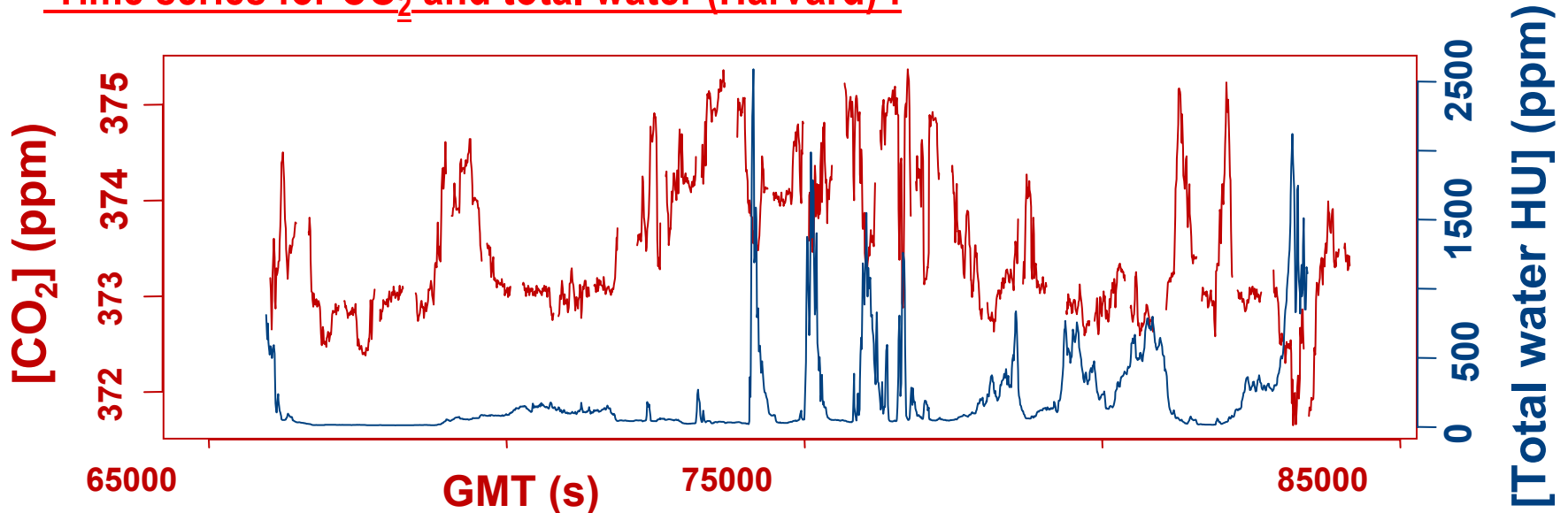


A CASE STUDY : JULY 16, 2002

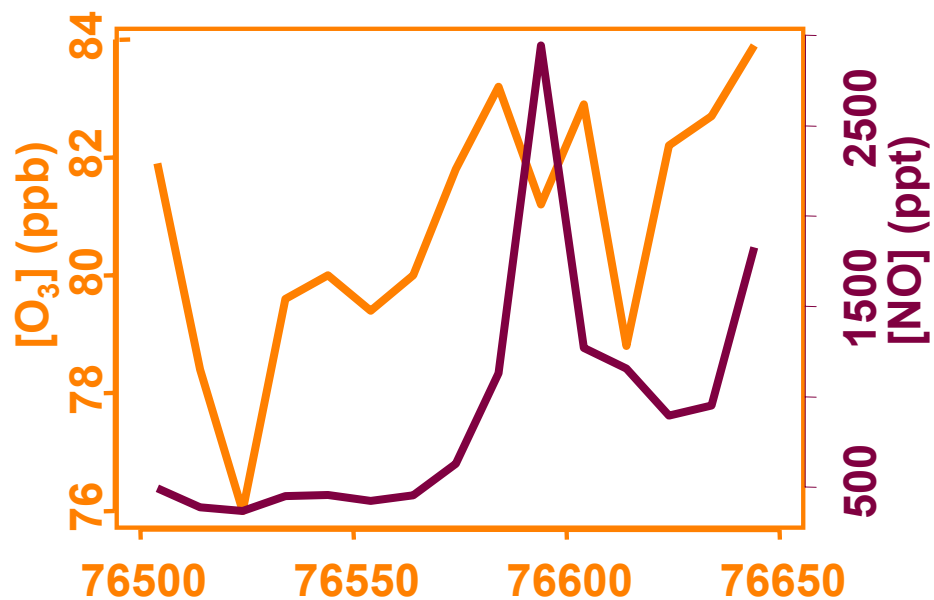
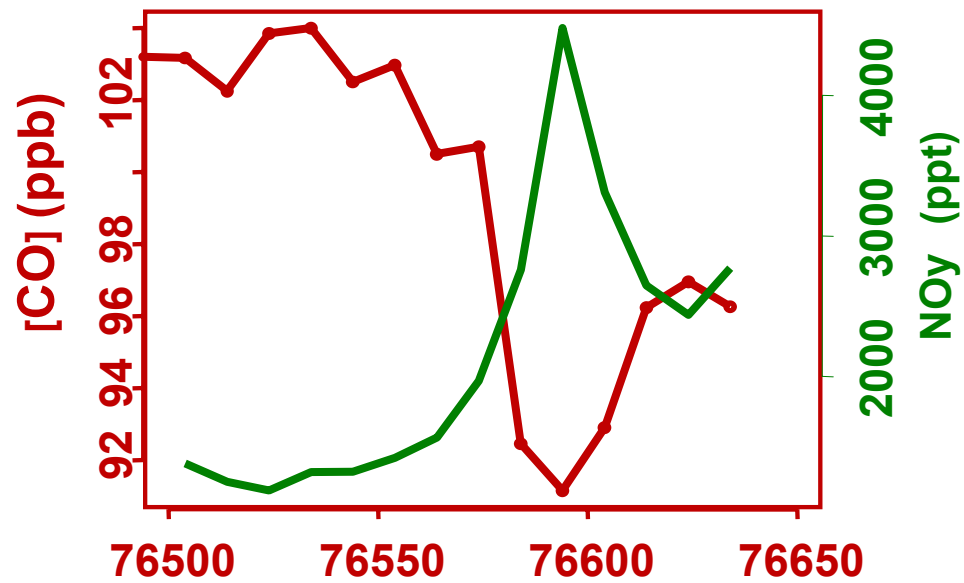
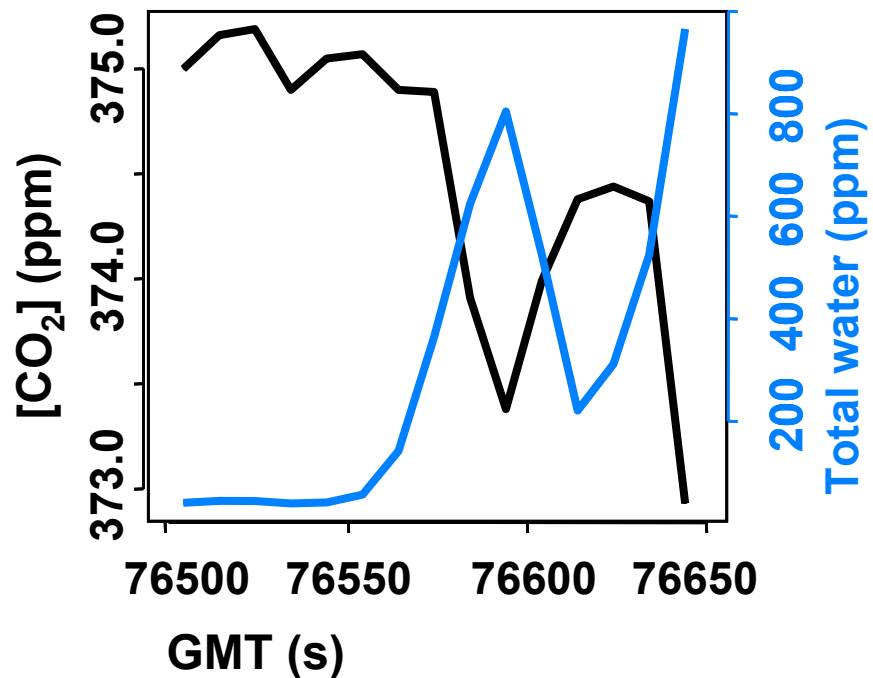
- CO₂ altitude profile averaged for whole flight :



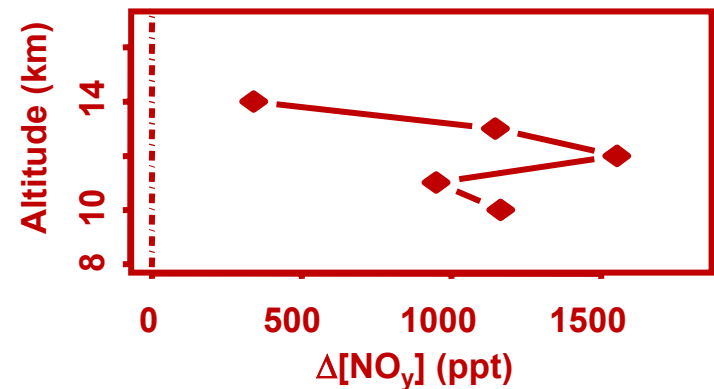
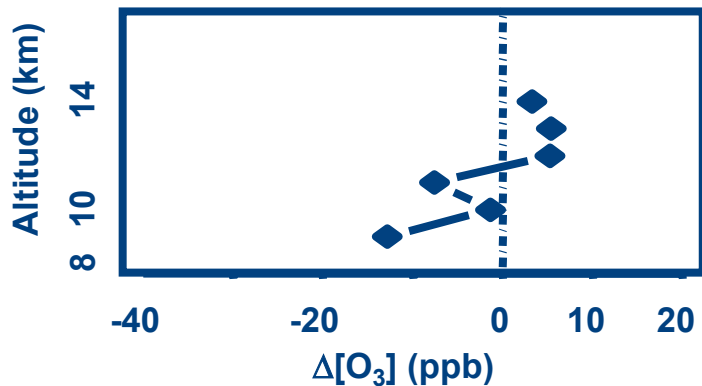
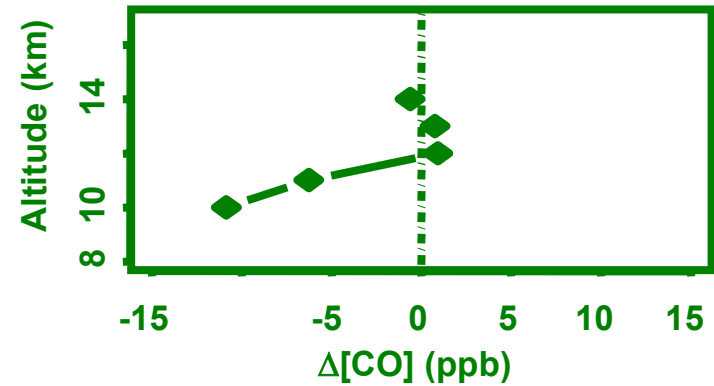
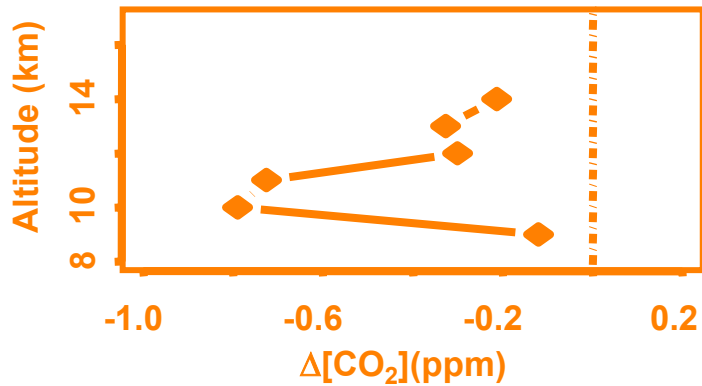
- Time series for CO₂ and total water (Harvard) :



An air layer example for July 16, 2002 (Z=12.4 km to 12.8 km)



July 16 : In cloud- out of cloud differences (Δ)
TROPOSPHERE ONLY



In cloud, there is a mixture of air from PBL and FT :
 $[\text{Anvil}] = a(z)[\text{PBL}] + b(z)[\text{FT}]$. But what are the dilution factors $a(z)$ & $b(z)$??

We measured [FT] but not [Anvil] precisely (not in the core).
We would need [PBL].

But no tracers data available in PBL!!

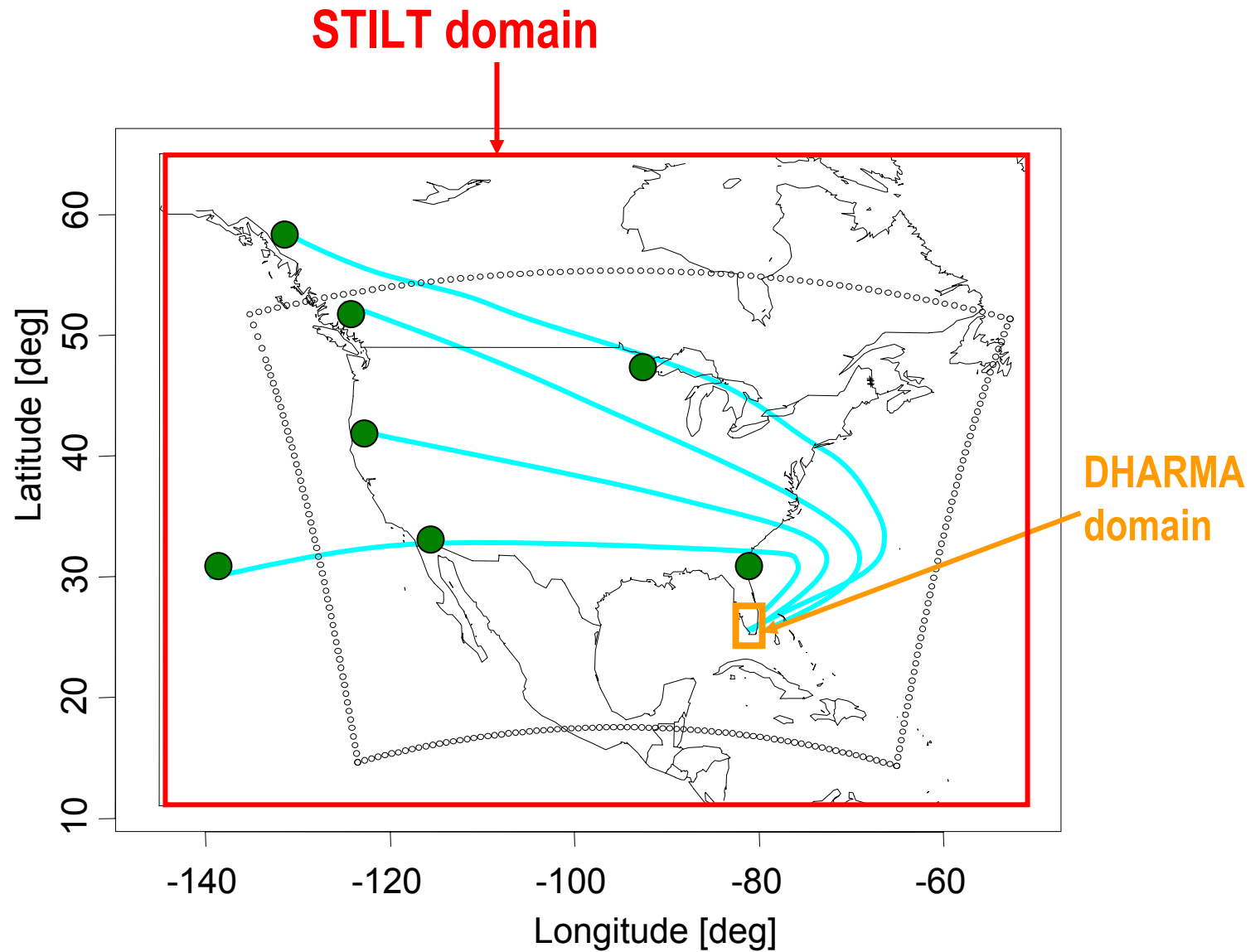


Strategy : STILT-DHARMA coupling

- STILT Stochastic Time Inverted Lagrangian Transport Model, *Harvard University* : A
Back trajectory model to generate PBL initial conditions

- DHARMA Distributed Hydrodynamic-Aerosol-Radiation-Microphysics Application, *NASA Ames* : A Mesoscale model to simulate the transport within the convective system

⇒ GOAL : get modeled CO₂ and CO profiles,
Compare to our CF data and determine dilution factors.



- **STILT boundary conditions:**
CMDL & COBRA data

STILT-DHARMA COUPLING:

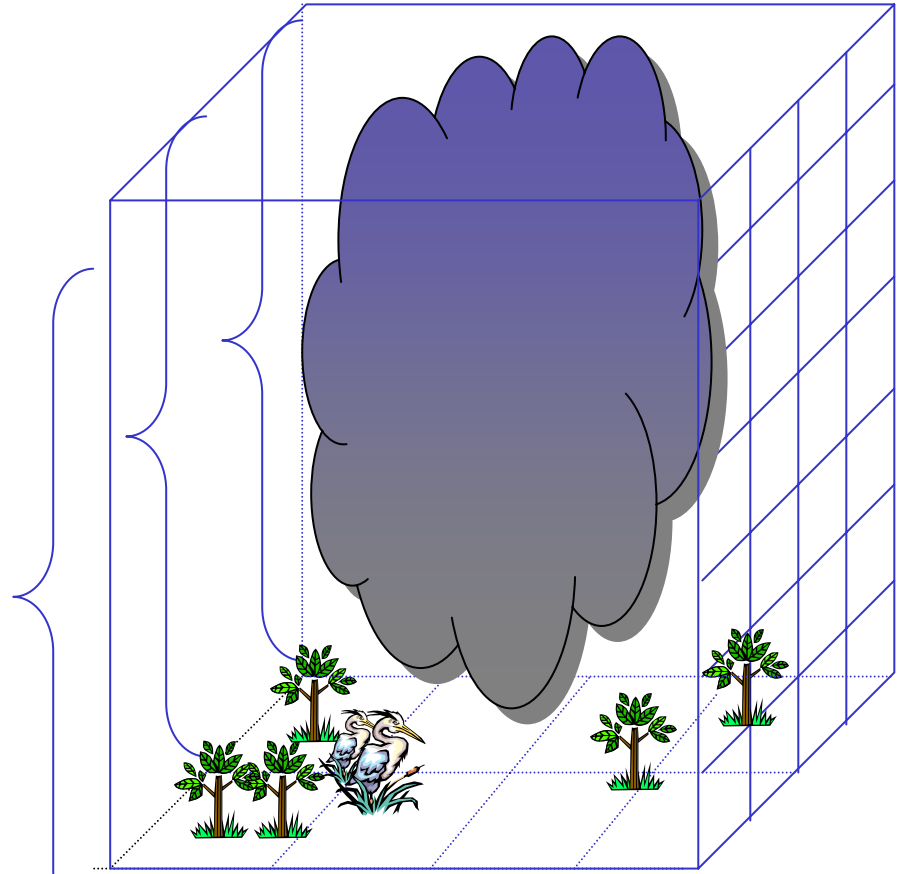
STILT PARTICLES OVER USA

DHARMA INITIAL DOMAIN
OVER FLORIDA

*EDAS/GDAS wind, temperature
and radiation assimilated data*



Surface-Atmosphere
EXCHANGES (COBRA)

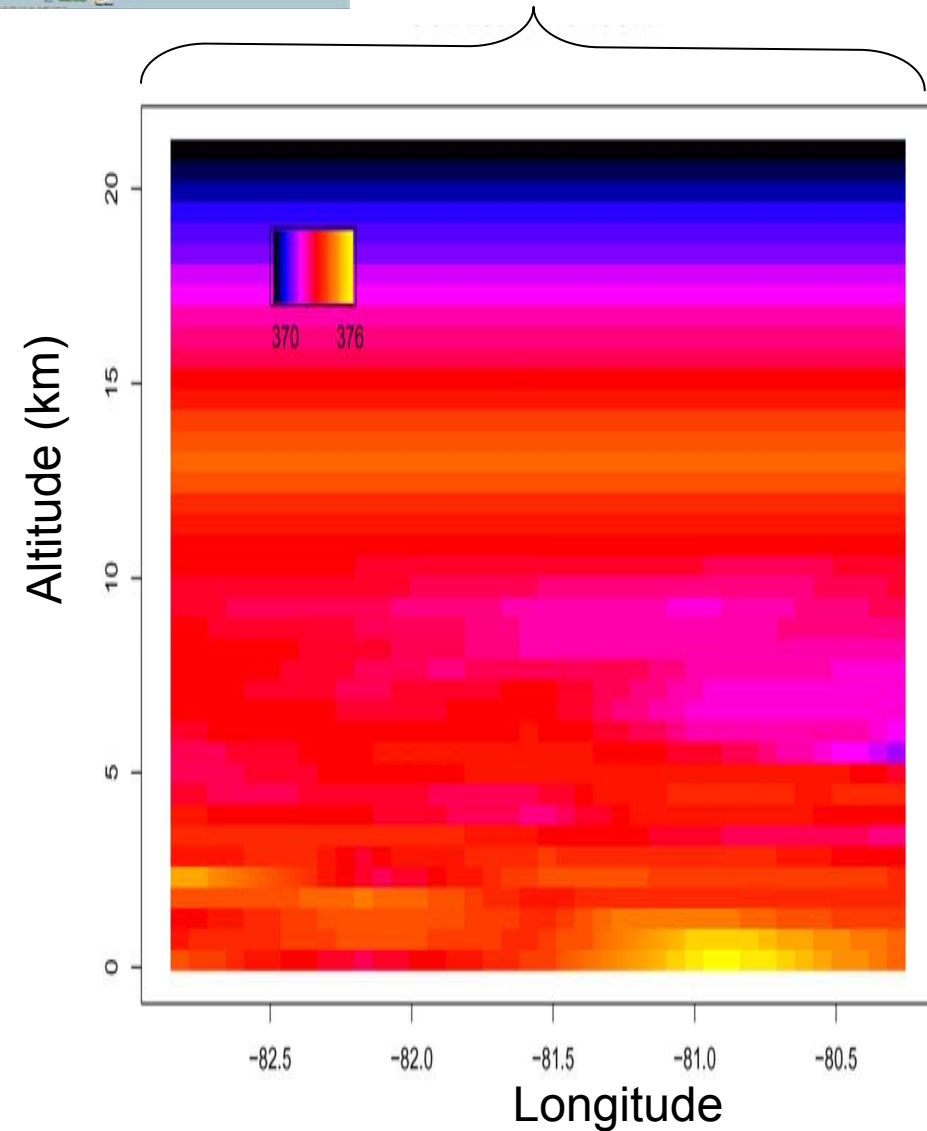


⇒ Lateral boundary condition from STILT:
CO₂ and CO concentrations

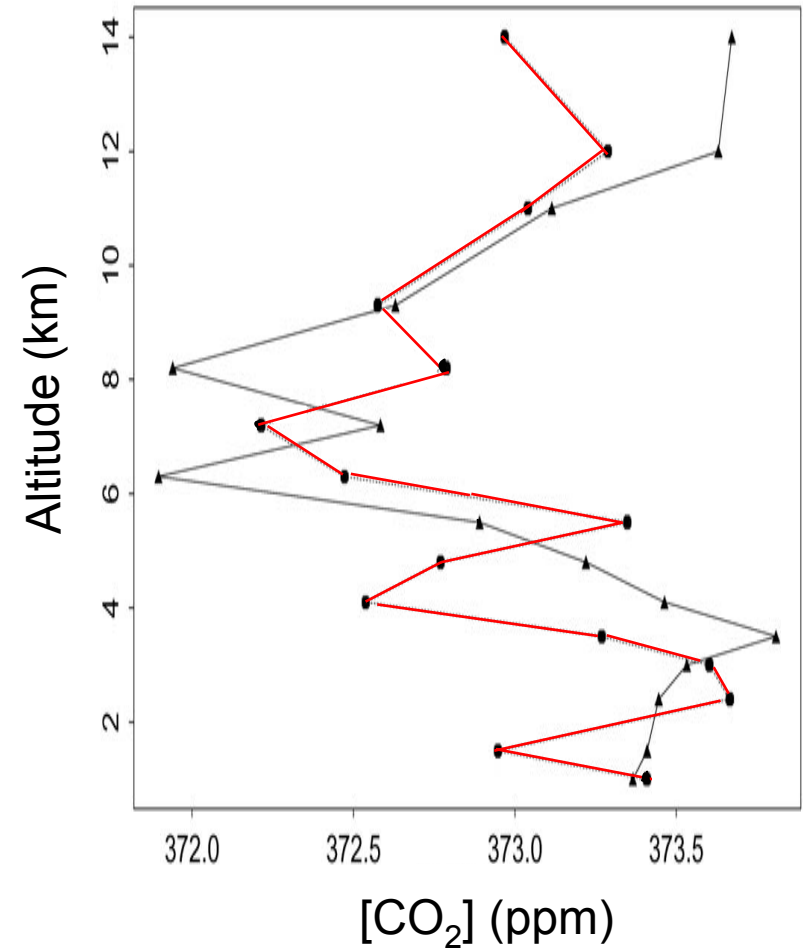
[CO₂] ALTITUDE PROFILES FROM STILT



Example : Domain mid-cut

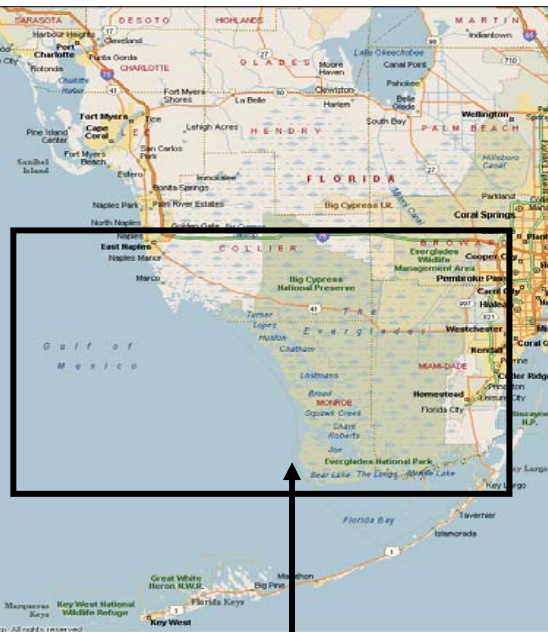


Comparison STILT-CRYSTAL :



Black : CRYSTAL CO₂ data, out of cloud

Red : STILT CO₂ output, out of cloud



**DHARMA final domain
for July 16**

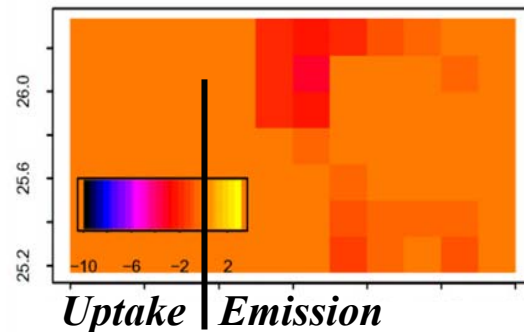
Fluxes are generated :

-for each vegetation type & for
Fossil Fuel emissions.

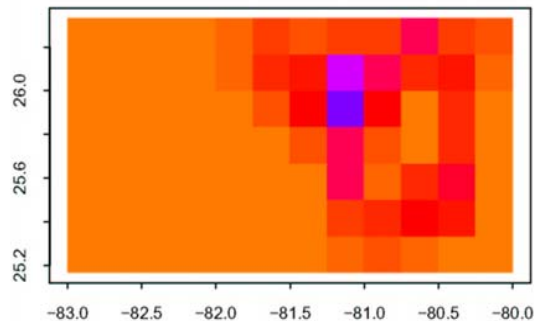
-every hour from 15h to 21h

CO₂ and CO fluxes for DHARMA domain

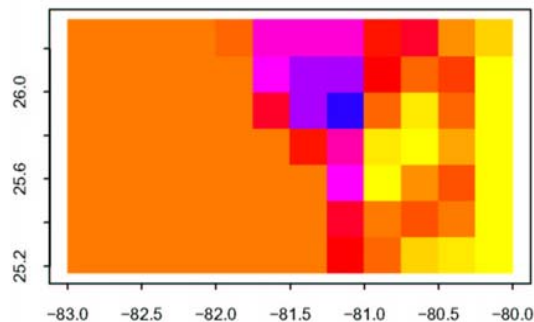
FORESTS



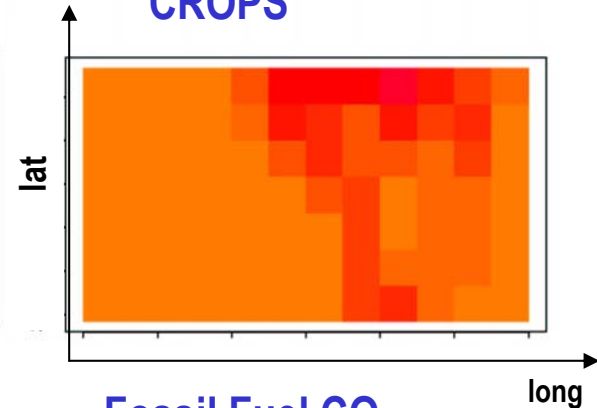
SHRUBS



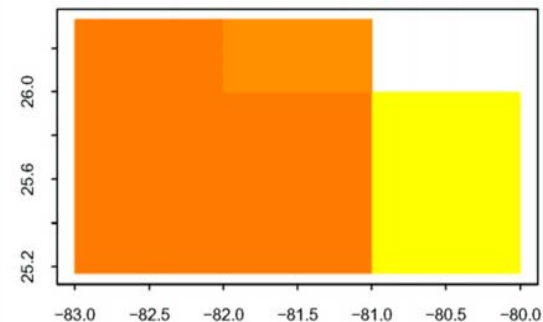
FLUXES for CO₂



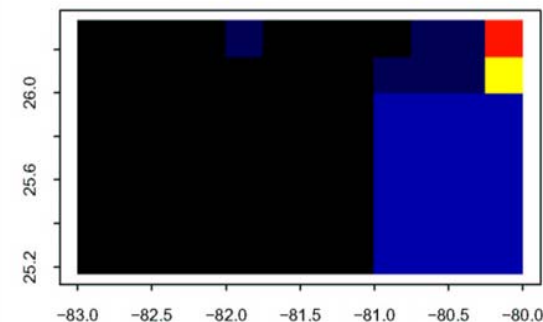
CROPS



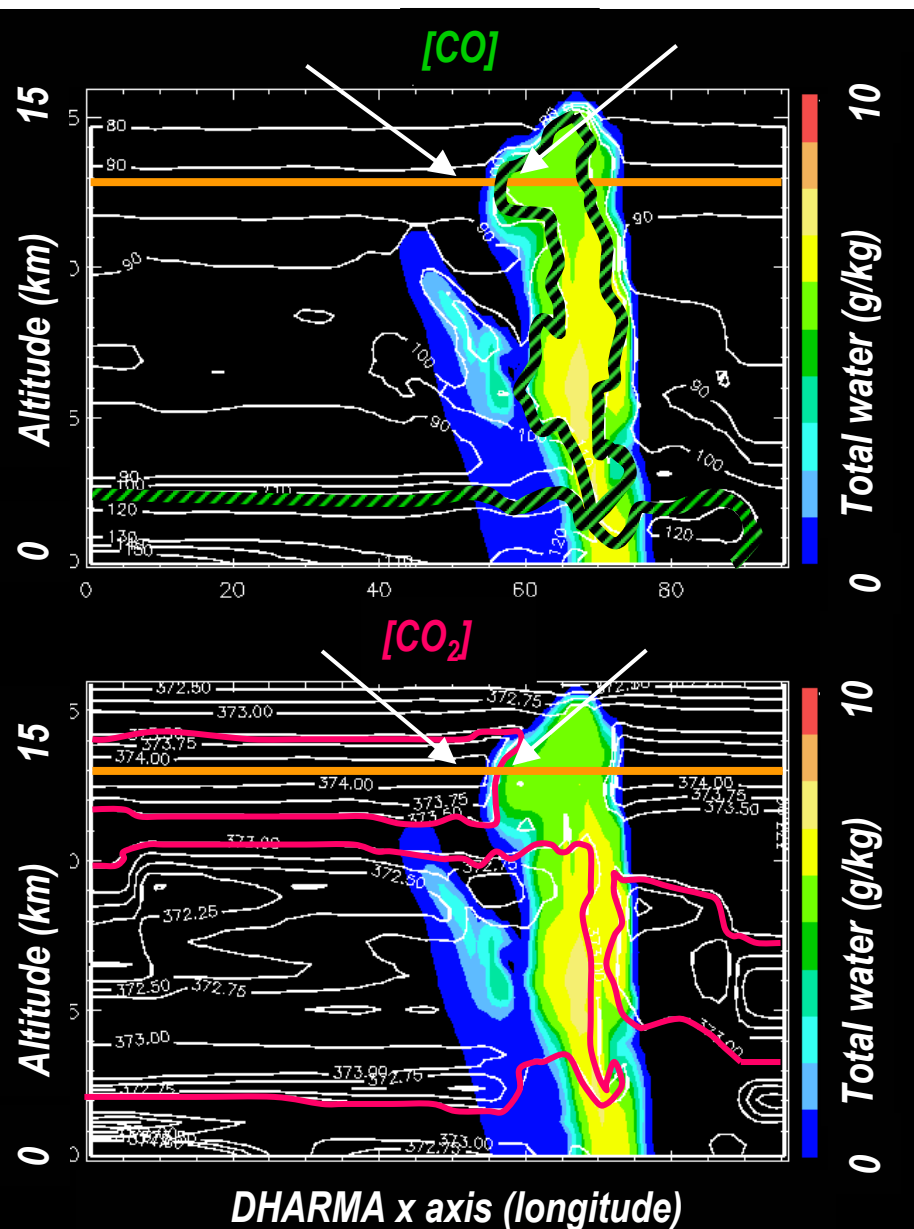
Fossil Fuel CO₂



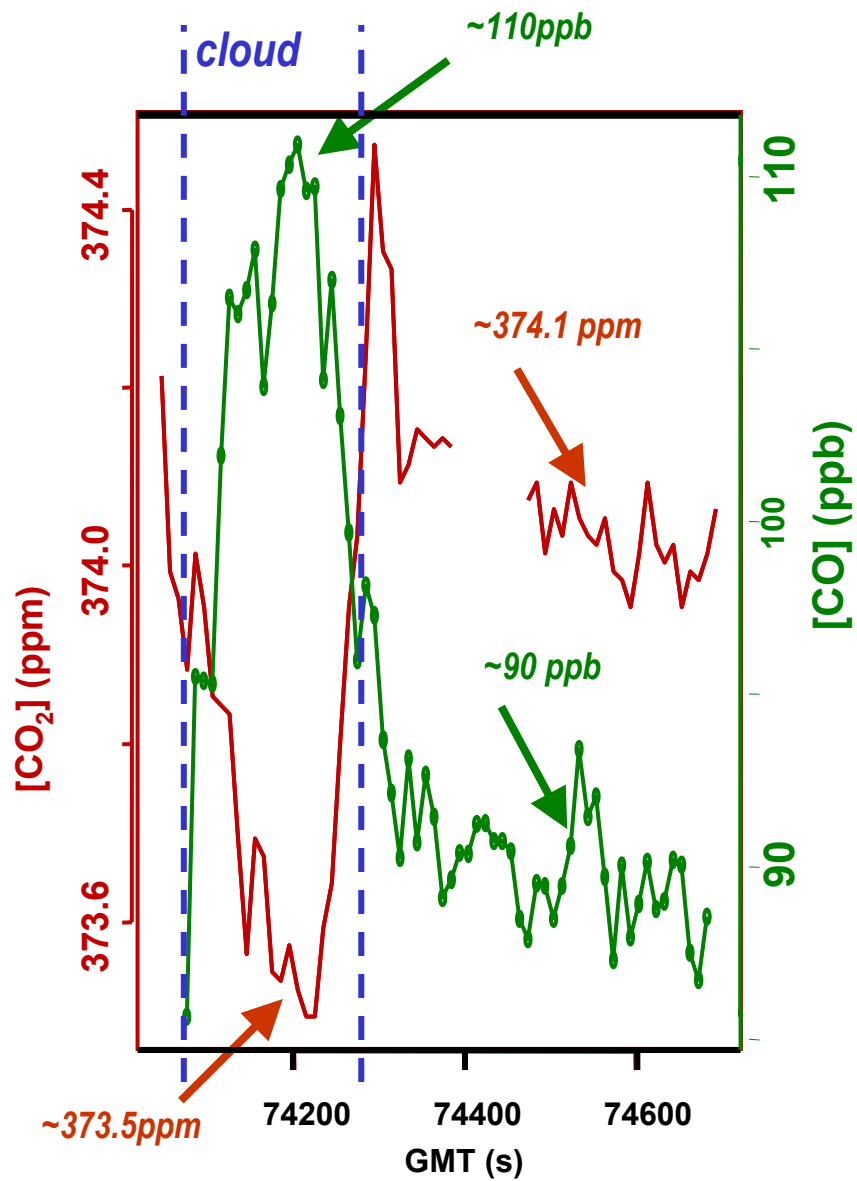
Fossil Fuel CO



DHARMA :
 $\Delta\text{CO}_2 \approx 0.5 \text{ ppm}$ $\Delta\text{CO} \approx 20 \text{ ppb}$

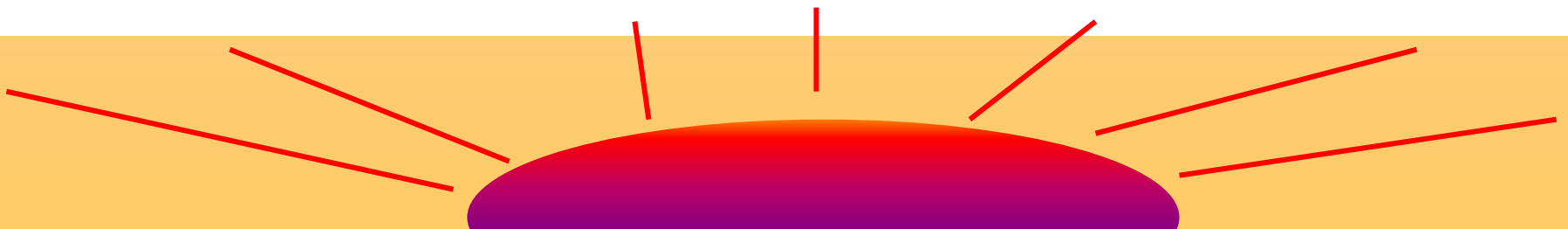


CRYSTAL-FACE :
 $\Delta\text{CO}_2 \approx 0.6 \text{ ppm}$ $\Delta\text{CO} \approx 22 \text{ ppb}$

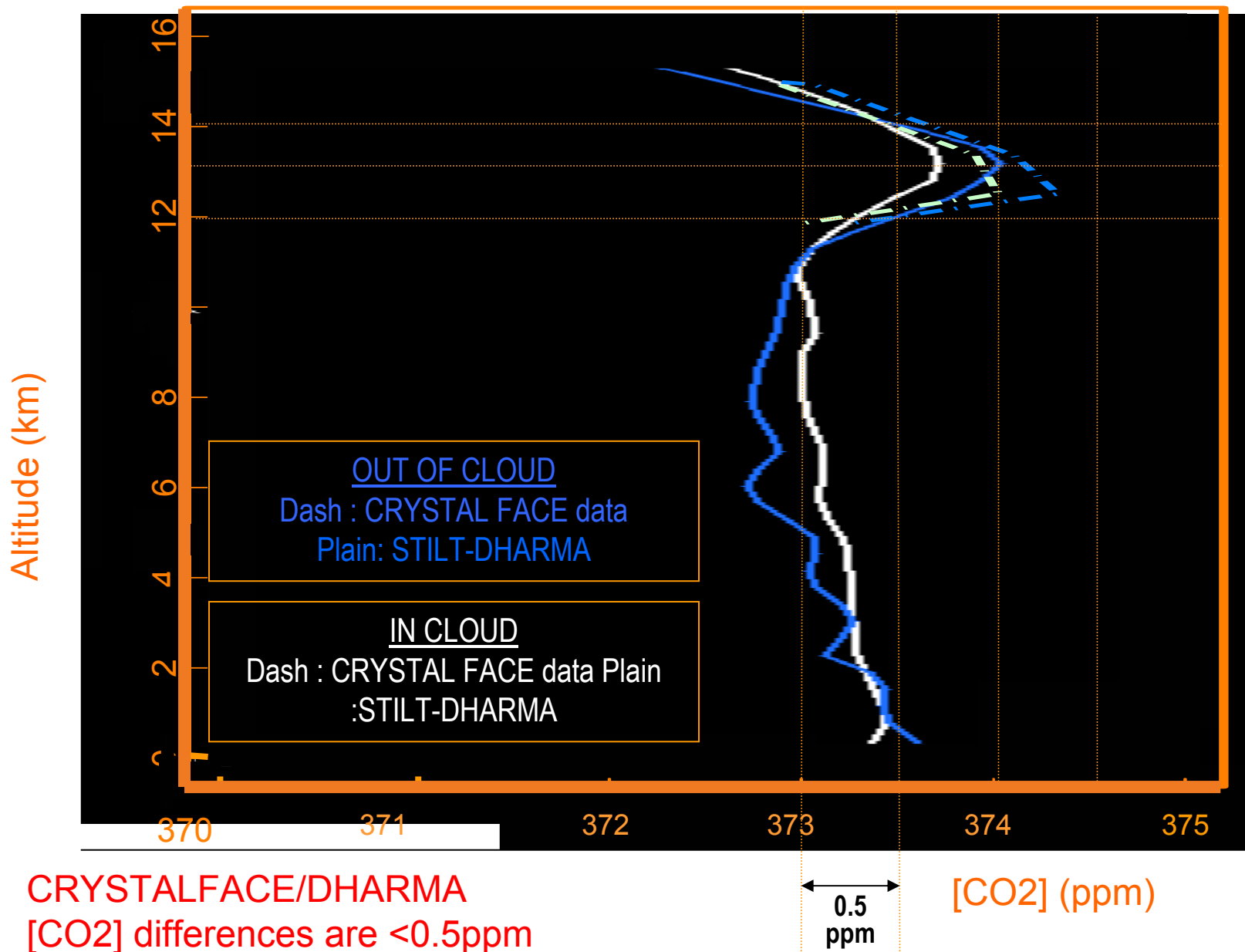


Conclusion & future work

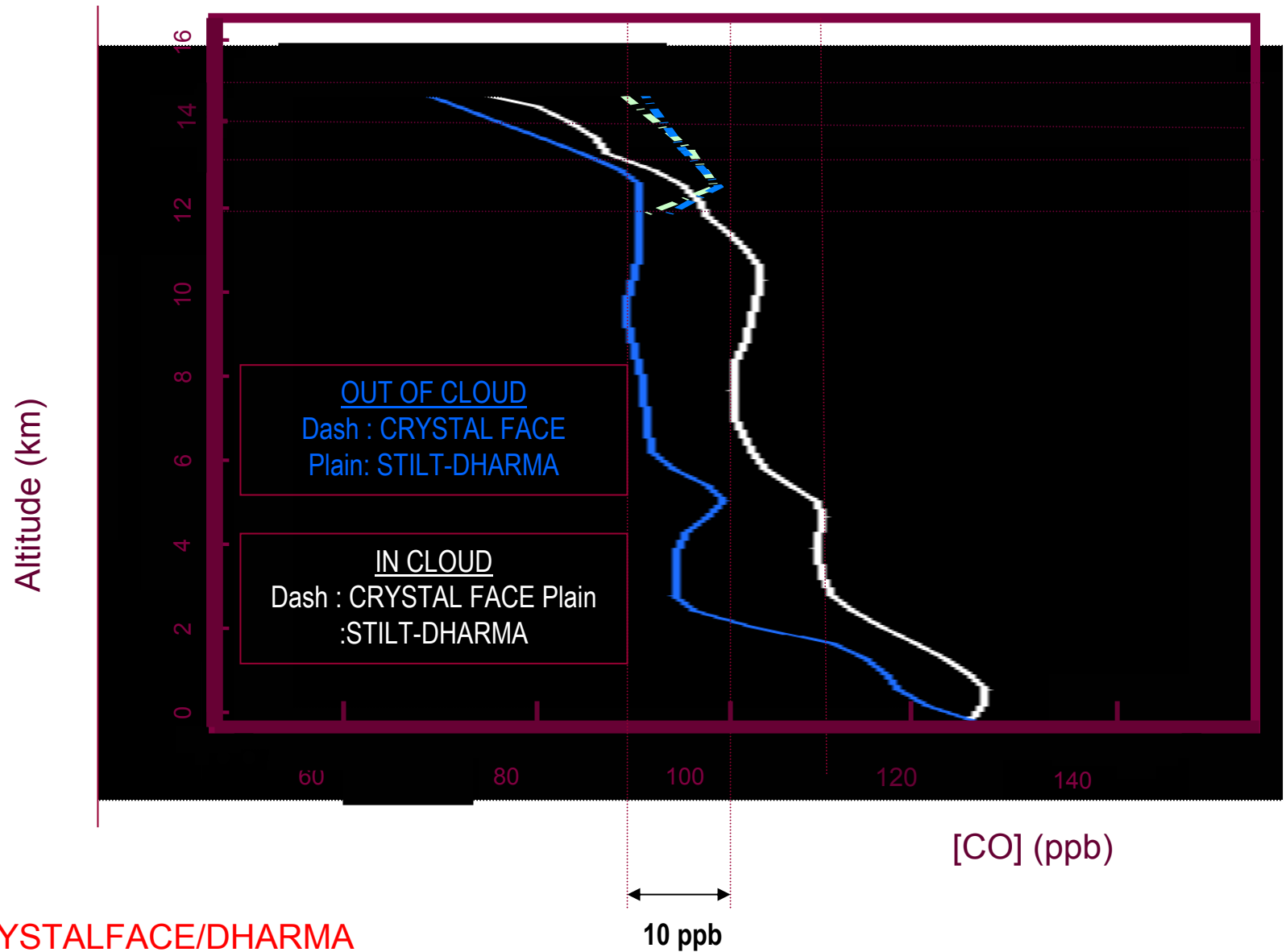
- CO₂ and CO data can well constrain models to study transport processes.
- The coupling of STILT and DHARMA provided promising results to better understand transport processes in convective systems.
- This study supports the fact that data are really needed in the PBL and around the storm (inflow regions) for this kind of analysis.
- Tracers analysis can be very powerful if well planned : measurements should be done in regions where gradients are strong. STILT can be used to predict those and choose proper locations for future campaigns.
- Our next goal is to pursuit work to get dilution factors and understand where the air up drafted and entrained was coming from.



COMPARISON of CRYSTAL FACE data & DHARMA results :
In-cloud & Out of Cloud Averaged Altitude Profiles (18h-21h) for CO₂



COMPARISON of CRYSTAL FACE data & DHARMA results :
In-cloud & Out of Cloud Averaged Altitude Profiles (15h-21h) for CO



CRYSTALFACE/DHARMA
[CO] differences are <8 ppb

Tracers' **CONCENTRATIONS** and **RATIOS** are function of the air mass **ORIGINS** :

- **Clean oceanic air : background**

[CO]=74ppb * [CH₄]=1756ppm * [NO_x]= 400ppt * [O₃]=20ppb * [CO₂]~ 373ppm

- **Biosphere : CO₂** Ex. CO₂ diurnal cycle at Harvard Forest

- **Biomass Burning : $\Delta\text{CO}/\text{CO}_2$ (+7) $\Delta\text{CH}_4/\text{CO}$ (+0.27)**

- **Fossil Fuel combustion : $\Delta\text{CO}/\text{NO}_y$ (+12.5) $\Delta\text{CO}_2/\text{CO}$ (+0.03ppm/ppb)
 $\Delta\text{CH}_4/\text{CO}$ (+2.54)**

- **Stratosphere : O₃>200 ppb H₂O<20ppm**

**CRYSTAL FACE data for CO₂, CO, O₃ and NO_y
measured on WB-57F in UT/LS are available.**

STILT-DHARMA COUPLING :

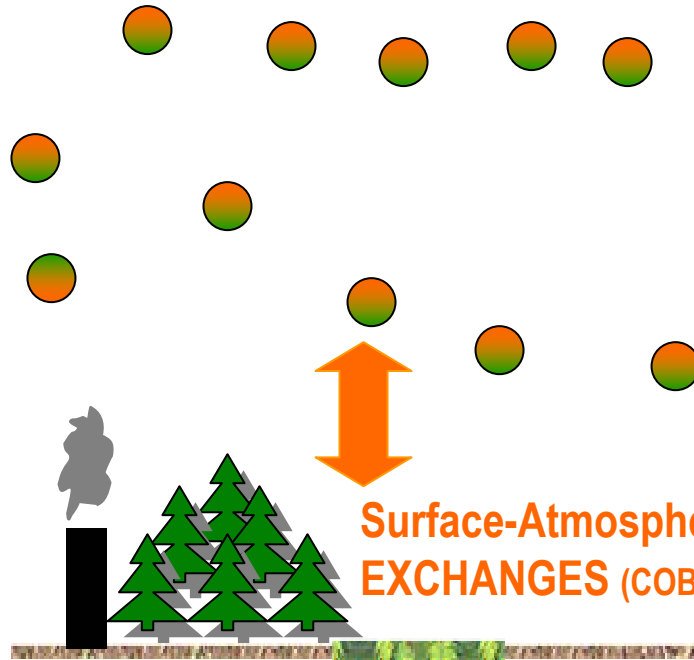
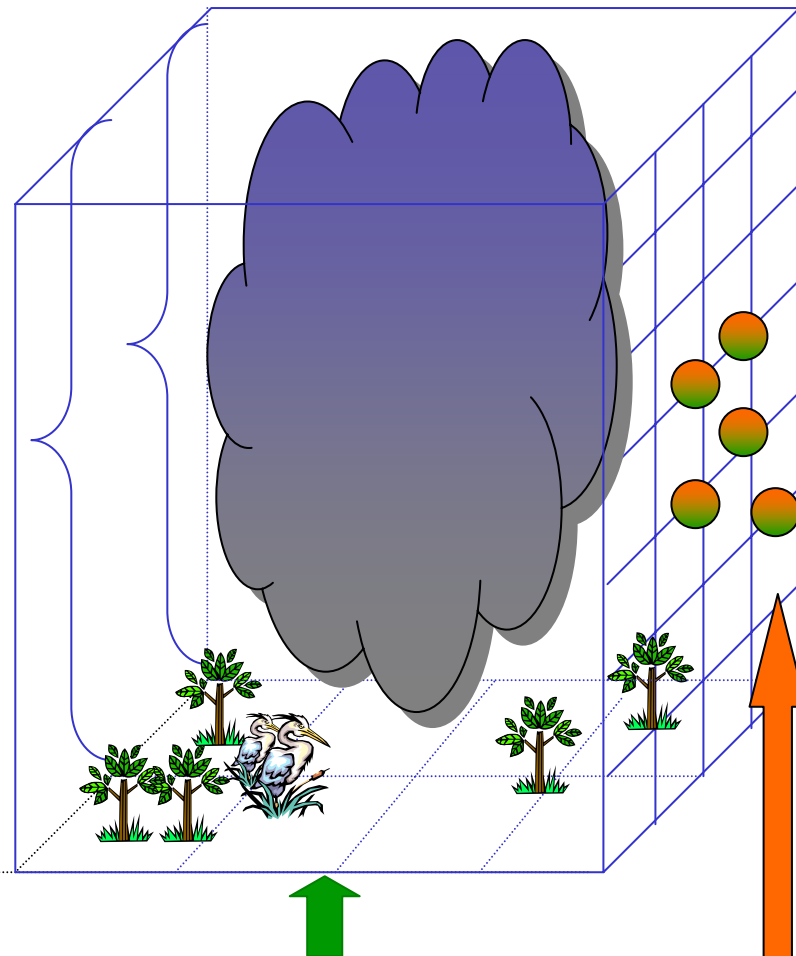
**DHARMA INITIAL DOMAIN
OVER FLORIDA**

STILT PARTICLES OVER USA



*EDAS/GDAS wind, temperature and
radiation assimilated data*

STILT BOUNDARY CONDITIONS



**Surface-Atmosphere
EXCHANGES (COBRA)**

Surface boundary condition :
CO₂ and CO fluxes (Ameriflux)

Lateral boundary condition from STILT: **CO₂ and
CO concentrations**